École Polytechnique de Montréal

INF8808E – Data Visualization

Project Plan

«Latency Tech - Visualization of 5G Network Latency Metrics»

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Table of Content

1. Context

1.1 Background

With the rapid growth of data-intensive applications and the increasing demand for low-latency communication, 5G networks have emerged as a critical infrastructure for delivering high-speed and reliable connectivity. In order to optimize the performance of these networks, it is essential to monitor and analyze the latency, or response time, between different points within the network.

A network latency is the time delay experienced by data packets when they are transmitted across a network. It affects the performance, responsiveness, and user experience of network-dependent applications and services. The importance of monitoring network latency can be attributed to several factors, knowing latency helps administrators identify possible causes of poor performance, such as network congestion, hardware problems, or configuration errors. It directly impacts the responsiveness of applications and services and network administrators can identify bottlenecks and rectify them by monitoring latency. On the other hand Service Level Agreements (SLAs) often include latency requirements. The monitoring of latency ensures compliance with these agreements and helps detect deviations that may require immediate attention.

1.2 Objective

This project aims to achieve several key objectives. Firstly, real-time visualization of both granular and aggregated latency data provides a visual representation of network performance, allowing operators to monitor the behavior of the network in real-time. This visualization helps identify any abnormalities or patterns that may arise, enabling proactive troubleshooting and optimization.

Secondly, the project aims to generate real-time predictions based on the collected latency data. By leveraging machine learning and time-series analysis techniques, the system can forecast future latency values, allowing operators to anticipate potential performance issues and take preventive actions.

Another important aspect of the project is the comparison of measurement protocols. By analyzing latency measurements from different IP protocols, network operators can gain insights into the relative performance of these protocols. This comparison aids in identifying the most efficient and reliable protocols for specific use cases, guiding network configuration and optimization decisions.

1.3 Target User

Network latency monitoring is critical for businesses that rely heavily on network-based services such as e-commerce platforms, online gaming, and real-time communications. This ensures that the services provided are responsive, reliable and provide a seamless user experience. Businesses

can maintain a competitive edge in the market by monitoring delays and proactively addressing issues.
The audience of network latency visualization in any organization can be divided into two main groups, Technical teams and Managers and Business decision-makers.

1.3.1 The technical team's perspective is as follows

Technical teams in the company need this information to respond effectively to their assigned tasks. As an example, network engineers can identify bottlenecks and optimize network configurations by knowing network latency. Thus, they can make informed decisions about network architecture, hardware upgrades, and topology changes. Moreover, The monitoring of network latency provides insight for Web and Application Developer teams into the performance of applications that rely on the network.Then development can be optimized by understanding latency patterns, improving user experience, and ensuring data transmission is efficient. Last but not least, monitoring network latency is crucial for the security team, it helps them detect potential security breaches. A security team can enhance network security by monitoring latency patterns, investigating potential threats, and taking proactive measures. By doing so, they are able to identify and respond to security incidents in a timely manner.

1.3.2 The business perspective is as follows

As well as the technical team, the management team and decision-makers need this information. For example, by understanding latency requirements and performance expectations can ensure that a company's services are suitable to meet customer expectations and provide a successful user experience. Moreover, they can inform decisions about network investments, resource allocation, and strategic planning for improving business operations. Additionally, business planners can identify potential areas for improvement. Using it, business team evaluate how network latency affects service delivery, customer satisfaction, and revenue generation.

2. Dataset

The latency is initially measured by a software provided by Latence Tech at some strategic points in the network. It then follows a stream data pipeline to process the data and add predictions.

Variable	Type	Description	Typical values/range
Time	Timestamp	Real time value	hh:mm:ss
Protocol	String	There are several IP protocols used such as ICMP, tcp, http ,https, TWAMP…	ICMP, Tcp, Http , Https, TWAMP
Latency	Float	The time delay occurs between the initiation of a request and the corresponding response	Depends
Latitudes	Float	The horizontal position (X coordination)	["x", "y"]
Longitude	Float	The vertical position (Y coordination)	["x", "y"]
Types of data	String	The latency in the network and application	{'Application','Network'}
Forecasted maximum latency	Float	Predicted maximum value of latency based on existing data	Depends on latency
Forecasted minimum latency	Float	Predicted minimum value of latency based on existing data	Depends on latency
Confidence level	Float	The probability of getting close to the same estimate if you repeated your experiment or resampled the population	Percent
Volatility	Float	Measure of dispersion of short-term returns	About 1%

Application type	String	the specific type or category of software application that is associated with the network traffic	Web Browsing Email Video Streaming Voice over IP (VoIP) Online Gaming File Transfer (FTP, SFTP) Database Operations Cloud-based Applications or Services Social Media Applications E-commerce Platforms
Pocket loss %	Float	refers to the failure or inability of a packet of data to reach its intended destination within a network	Depends on several factors

Table 1 - Dataset attributes and variables

3. Questions

In order to ensure that the visualization meets the needs of the users, provides meaningful insights, and is user-friendly and visually engaging. Our target questions can be divided into several categories. The following features are included: Latency History, Prediction, Site Comparison, and Anomaly detection.

- [ ] Latency History

  In this Part we are trying to Represent a typical Time-series chart to visualize the latency based on different metrics. For instance, Based on application or network or based on their protocols.

- [ ] Prediction

  In this part, We try to estimate the latency maximum and minimum based on current value.

- [ ] Site Comparison

  One of the interesting parts of the project can be comparing latency based on different available places by different aspects.

- [ ] Anomaly detection

In this section a graph represents all anomalies summaries (increase of latence etc.)

Question	Priority	Visualization
Aspect 1 : Latency history		
For different protocols, how does latency vary over time?	☆☆☆☆	**Visualization 6**
How does the average latency vary across different application types?	☆☆☆	**Visualization 2**
What is the average latency for all protocols and which one works better during the different time slots?	☆	
What is the current value for latency in each protocol?	☆☆☆☆	**Visualization 3**
Aspect 2 : Prediction		
What is the maximum and minimum forecast latency along with current state?	☆☆	**Visualization 5**
What will be the confidence level and Volatility in moment?	☆☆	**Visualization 5**
Aspect 3 : Site Comparison		
What is the most and least latency in different places based on different protocols?	☆☆	
What is the average latency over time for each site?	☆☆☆	**Visualization 4**
What is the current latency for a particular location and different protocols?	☆☆	**Visualization 1**
Aspect 4 : Anomaly detection		
Are there any unusual spikes in latency that we can highlight and flag in different protocols?	☆☆☆	**Visualization 6**
Which protocol is the most subject to anomalies?	☆☆	

Table 2 - Questions of interest and their priority

4. Mockups

4.1 Visualization 1

Questions:

What is the current latency for a particular location and different protocols?	✰✰

Description:

This visualization shows the Bubble geographical map of Canada. Here, three different provinces including Quebec, Ontario and Manitoba are highlighted and we have data for 3 different cities in each province.

The size of the circle shows the current latency value and the colors show each protocol. The colors chosen here are contrast colors to be differentiated easily.

In this visualization we can easily compare the latency of different protocols with each other and with different locations as well.

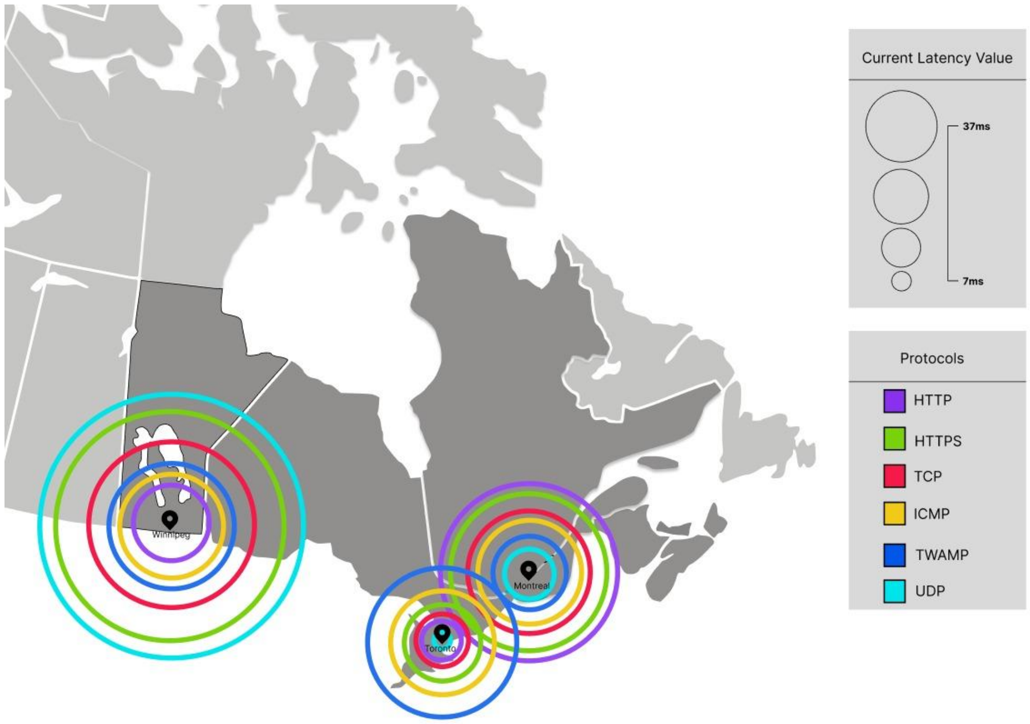
Interactions:

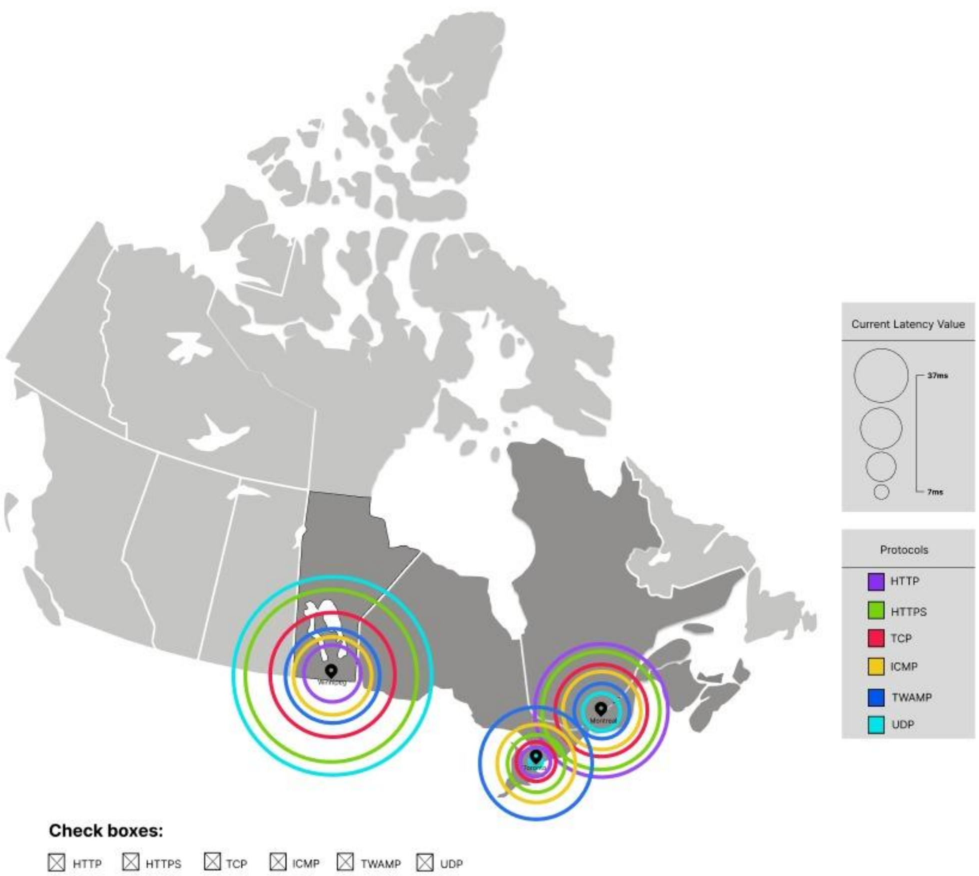
In this visualization, there are mainly 2 possible interactions for the user.

The first one is the checkboxes shown under the map. Users can choose the protocols they want to compare. It can be only one protocol in different areas or several protocols depending on the purpose.

The other feature is hover, when the user hovers the mouse over each circle of the map, a tooltip will be displayed. The tooltip provides the precise value of current latency in milliseconds. This way for the circles which are similar in the size, comparison would be easier.

Visualization:





4.2 Visualization 2

Questions:

How does the average latency vary across different application types?	✰✰✰

Description:

The chart is a bubble chart that visualizes the average latency for each application type. Here's an explanation of the chart components:

X-axis: The x-axis represents the number of records used for each application type. It indicates the sample size or the number of data points available for calculating the average latency of each application type. Frequency is used in the bubble chart to represent the number of records or data points available for calculating the average latency of each application type. It helps users understand the availability and reliability of data, make comparisons between different application types, and gain insights into latency trends over time. A larger frequency generally indicates a more accurate average latency measurement.

Y-axis: The y-axis represents the average latency of each application type. It shows the typical or average latency experienced by each application type. The higher the value on the y-axis, the higher the average latency.

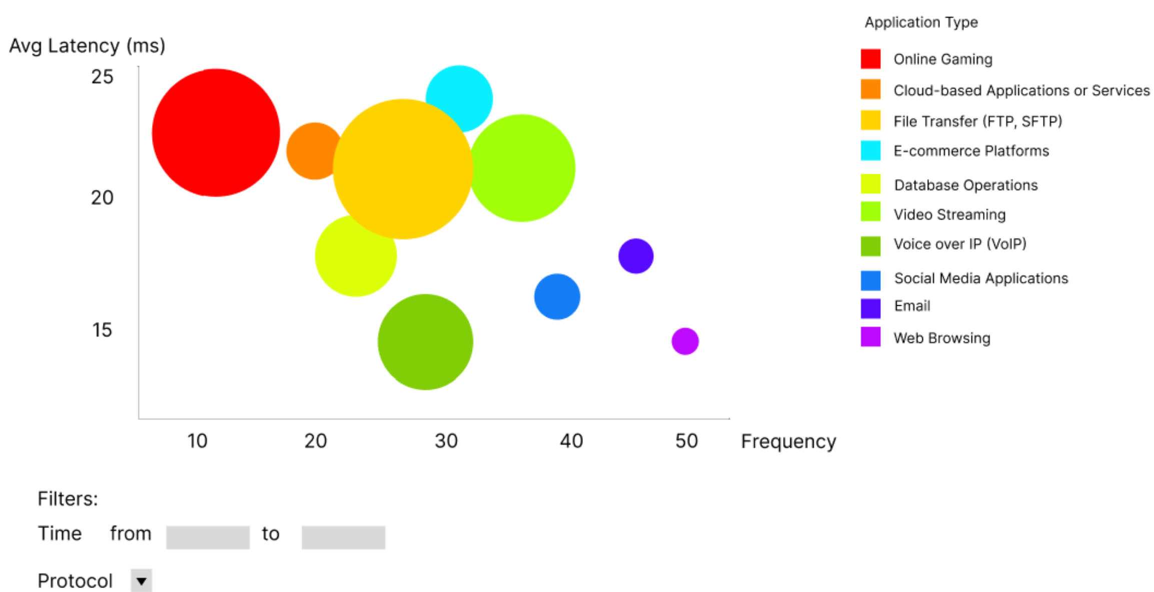
Bubble Size: The size of the bubbles represents the average packet loss of each application type. Larger bubbles indicate higher average packet loss, while smaller bubbles indicate lower average packet loss. This provides a visual comparison of the packet loss levels between different application types.

Bubble Color: The bubble color represents the application type itself. Each unique application type is assigned a distinct color, allowing for easy identification and differentiation between them.

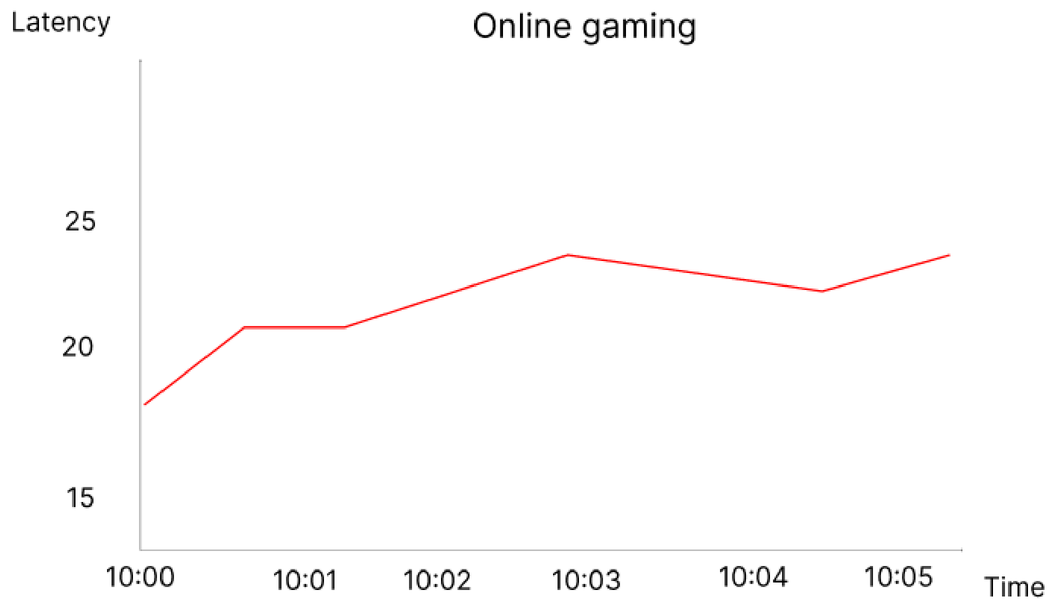
The bubble chart provides a visual representation of the average latency, packet loss, and sample size for each application type. The x-axis helps understand the availability of data for each application type, while the y-axis shows the average latency values. The bubble size indicates the average packet loss, and the bubble color identifies the specific application type.

By examining the chart, users can compare the average latency across different application types, identify variations in packet loss levels, and analyze the impact of sample size on the accuracy of average latency measurements. Additionally, by clicking on a bubble, users can access additional line charts to gain further insights into latency trends over time for the selected application type.

Interactions:
The user can select the application types from the checkboxes on the right. By hovering on bubbles the application type, average latency, and the average packet loss will be shown to the user. Moreover, by clicking on the bubble, another line chart appears that shows the exact amount of latency for the chosen application type in an interval.
The user can also filter the data (time or desired protocols) from the filter section.
By hovering on the second chart the user can see the exact time and latency amount.
Visualization:



By clicking on each bubble another chart appears:


Latency
Online gaming
25
20
15
10:00
10:01
10:02
10:03
10:04
10:05
Time

4.3 Visualization 3

Questions:

What is the current value for latency in each protocol?	☆☆☆☆

Description:

This visualization shows the gauge chart of the current latency of each protocol. When you put the cursor on a gauge there are two shaded bands representing ranges of latency depending on the criticality of the value, the more the value reaches the gray zone, the more the value is critical ranging from low to highly critical (criticality is determined by the normal behavior of the network).

- The two blue almost-circle parallel bars represent the current value measured at the time it's displayed,
- The arrow indicates whether the latency of the protocol is increasing or decreasing and the small value below it is the difference with the previous value

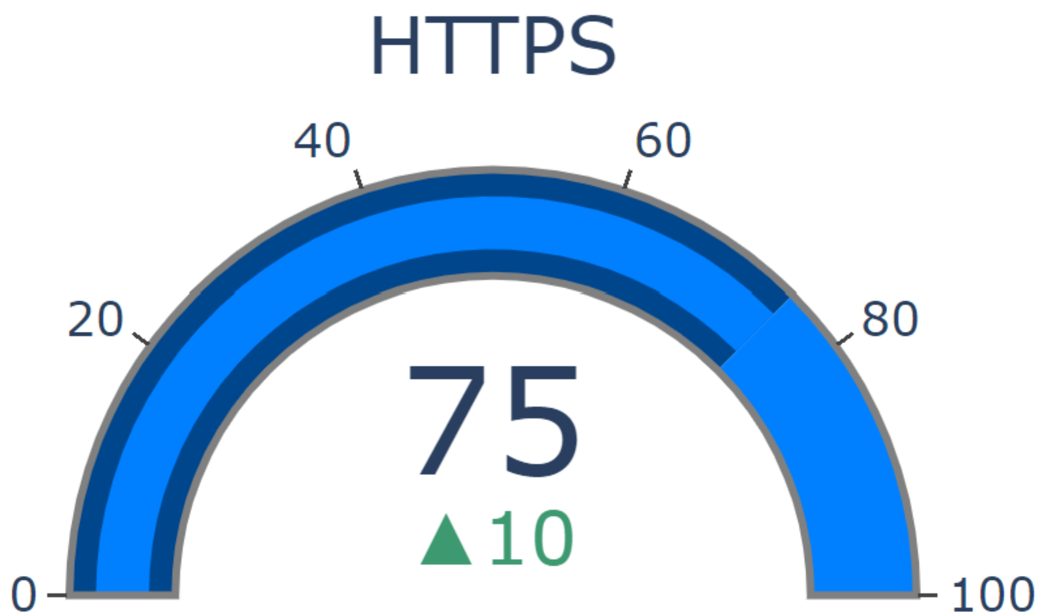
Interactions:

In this visualization, there is an hover interaction for the user. If he just puts the cursor over a chart the user will have a kind of zoom on the gauge of the protocol he is looking at. The user will be able to see the chart in more detail.

Visualization:

Visualizing the current latency of each protocol in ms

When you click on a specific gauge you get a zoom on the chart like the one below.



Visualizing the latency of the HTTPS protocol

4.4 Visualization 4

Questions:

What is the average latency over time for each site?	☆☆☆

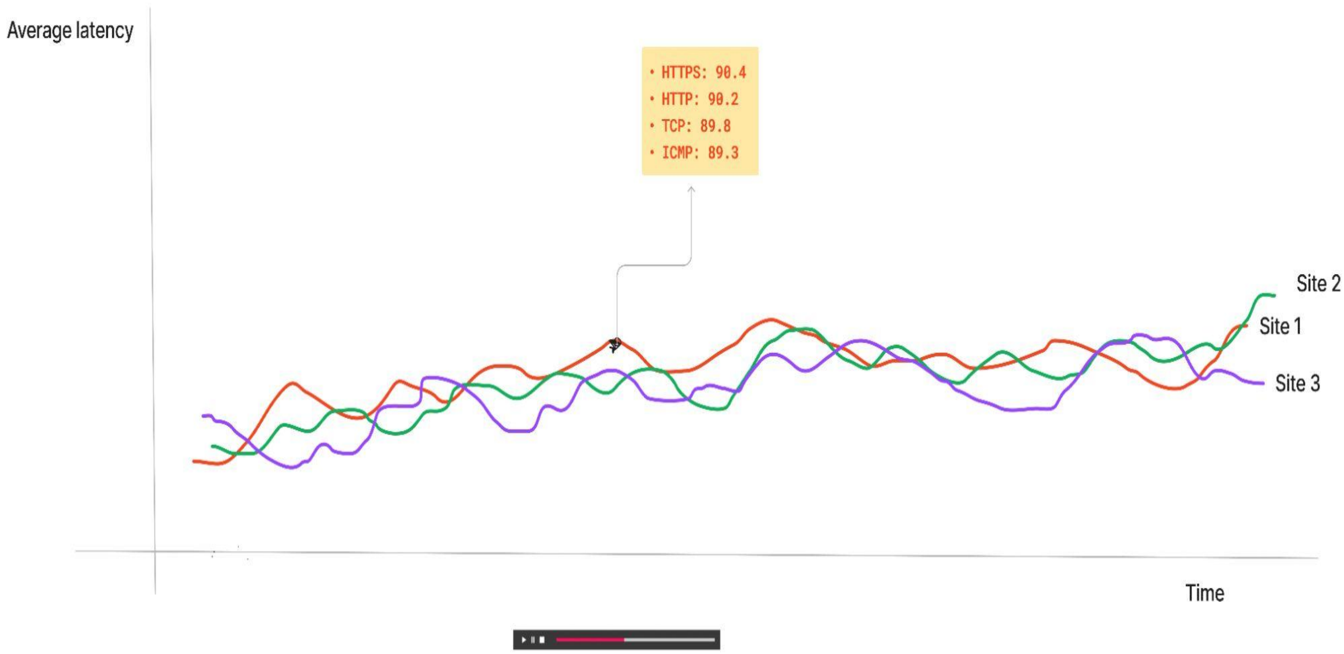
Description:
A line chart animation shows the average latency for three different sites, which include Quebec, Ontario, and Manitoba, over different time periods.
Time is represented on the x-axis, and average latency is shown on the y-axis. Three lines are displayed in this line chart, each representing one of the sites. Throughout the anime, the average latency rate across the three sites will be shown from the very beginning of the selected time period. Thus, not only can the audience see the average latency rate for a given period, but they can also compare the values between different sites over time.

Interactions:
In this visualization, the user will be able to see the average latency for all sites . User have two interaction option with this visualization:

- When User pauses the anime and clicks on any of the selected sites, he can see the average latency per different protocols in the selected site.
- Secondly, the user can select whether the average latency should be displayed per application or per network.

Visualization:

Select to see the average latency per: Network
Application



4.5 Visualization 5

Questions:

Aspect 2 : Prediction	
What is the maximum and minimum forecast latency along with current state?	✰✰
What will be the confidence level and Volatility in moment?	✰✰

Description:

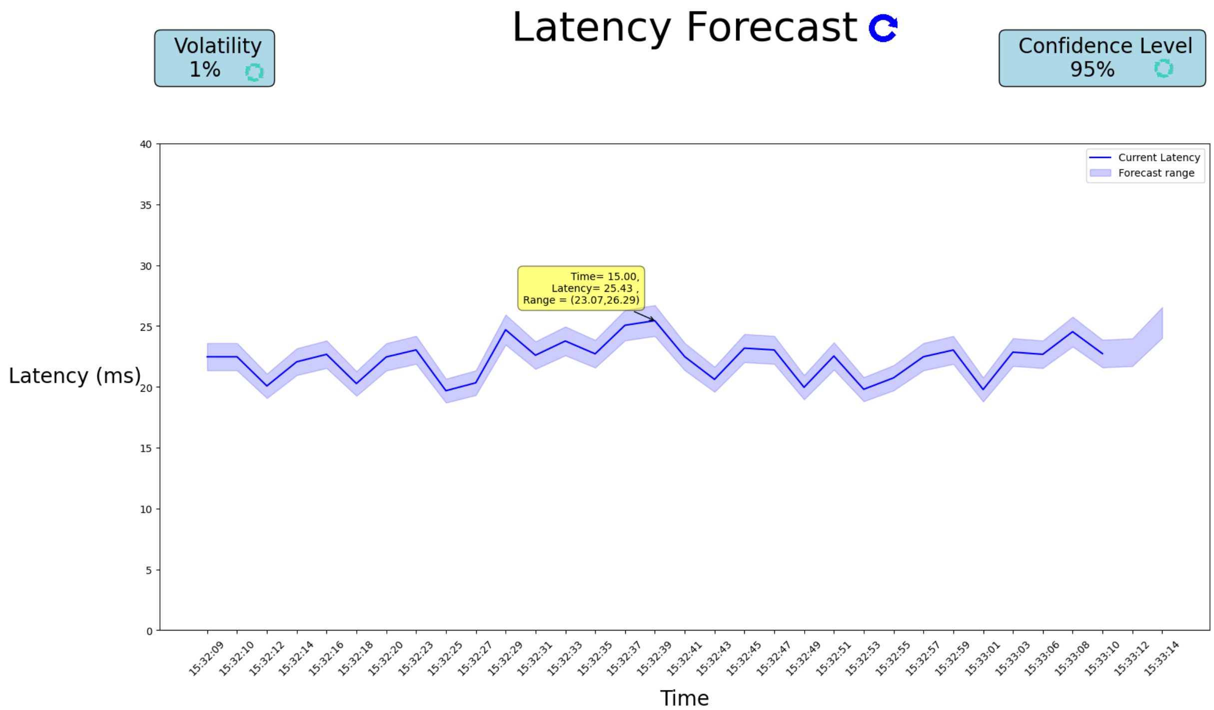
On the latency forecasting dashboard, you can see the maximum and minimum forecasting range of latency based on a model derived from an AI model. A graph consists of three parts:

1. The latency volatility
2. The confidence level of forecasting
3. Main graph with forecasting latency range

A new prediction of Latency will be received for every 5 packets (each packet of data was generated the latency after 1 or 2 seconds), and all three parts will be updated as a result. For the next upcoming data, you can see the range of data that will be created.

Interactions:
By clicking in each point you can see the Time, Latency and Range of data which was protected by the system.

Visualization:



4.6 Visualization 6

Questions:

Are there any unusual spikes in latency that we can highlight and flag in different protocols?	☆☆☆
For different protocols, how does latency vary over time?	☆☆☆☆

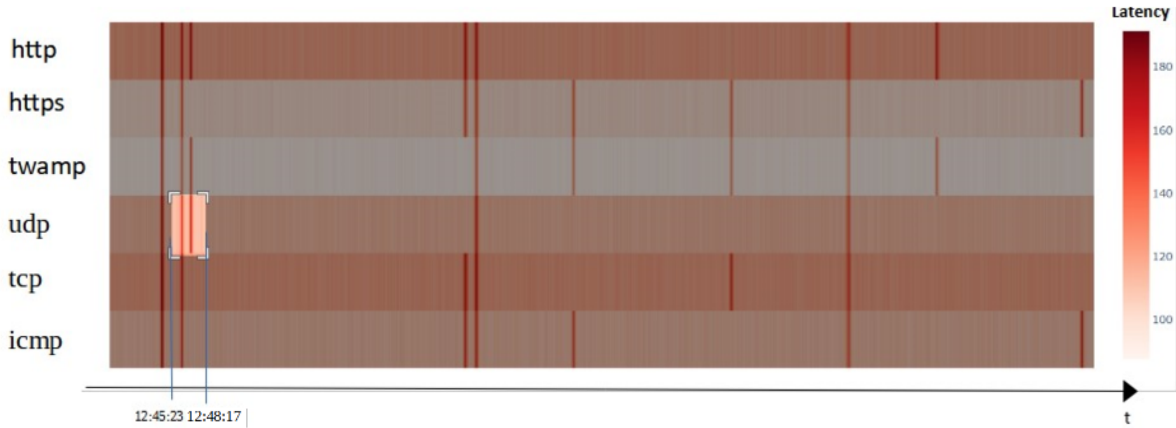
Description:

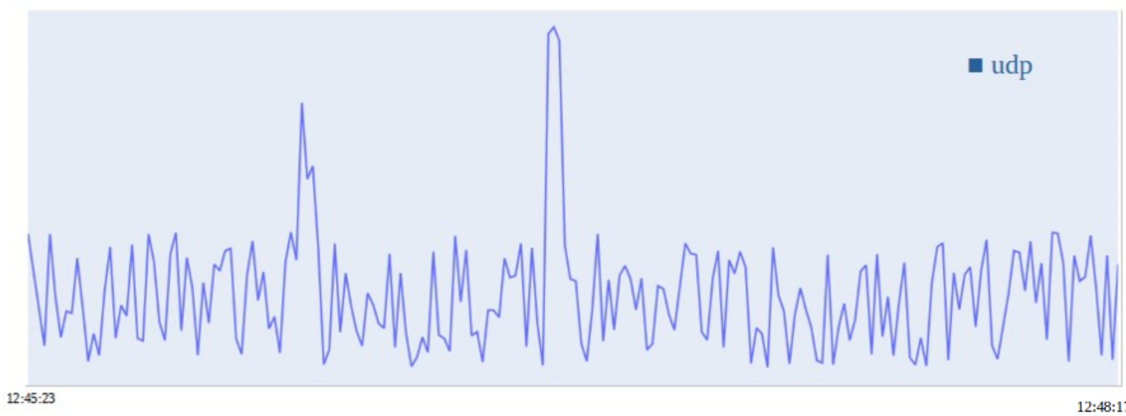
1. A heatmap of (time, protocol) -> latency that shows where there are pikes in latency.
2. A line graph that gives the details about one time window selected on the heatmap

Interactions:

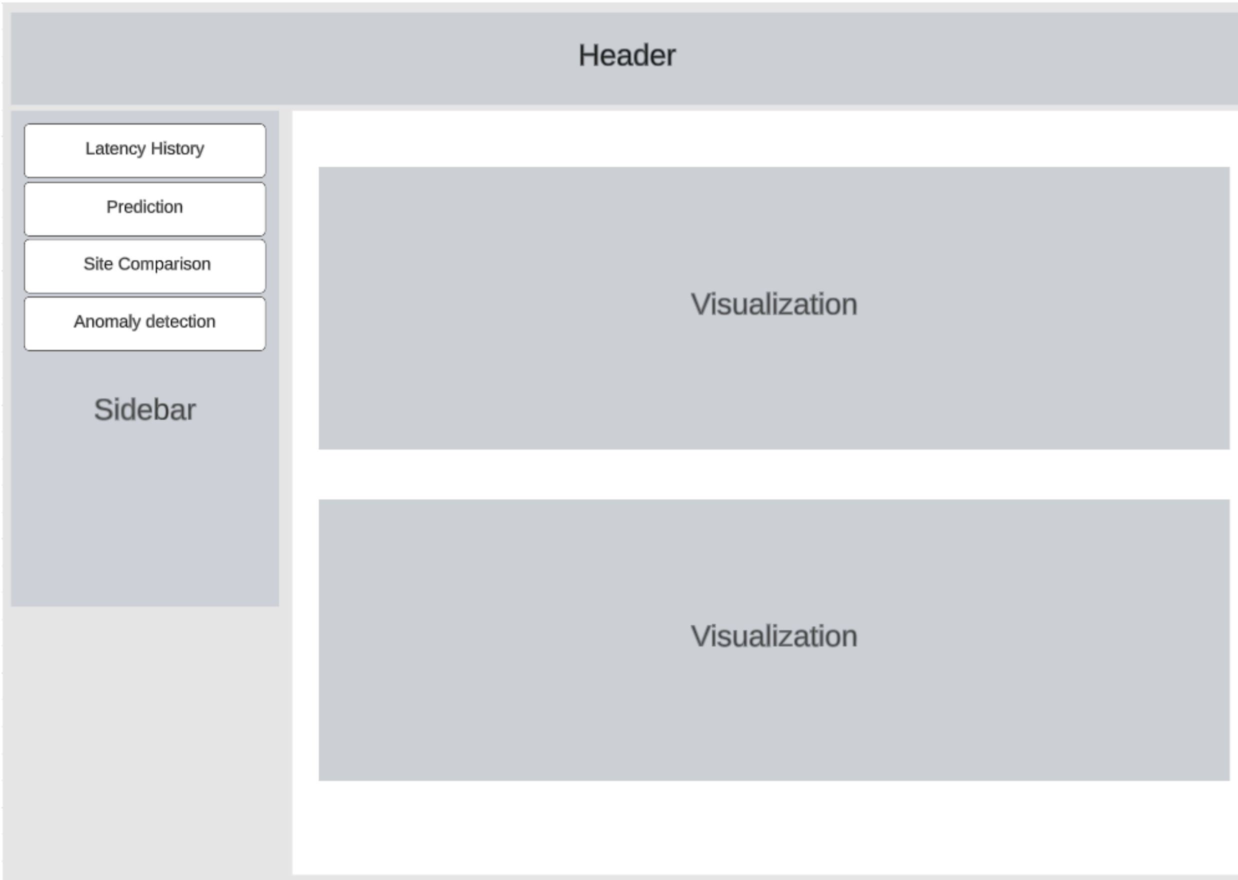
The user can select a time frame of a given protocol on the heatmap to zoom in this time window on the line graph.

Visualization:





4.7 Overall Paradigm



In the above template we have one sidebar and by clicking on each one different option, related visualization will be displayed.